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Relation of Temperature and Seed Moisture to the Viability of Stored Soybean Seed

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INTRODUCTION

Despite the importance of the soybean crop comparatively little has been published on the behavior of the seed in storage.

Oathout (*4*) reported that, if the moisture content of soybean seed was appreciably above 14 percent, temperature and ventilation were critical in relation to its spoilage under conditions in Illinois. Spencer (*6*) observed that soybeans stored under natural conditions in Trinidad lost viability almost completely in 10 months but retained full viability for this period in cool storage (55° to 60° F.). Ramstad and Geddes (*5*), using soybean seed of different moisture contents sealed in glass jars and stored at room temperatures in Minnesota, noted an increased rate of loss of viability as the moisture content was raised from 9.4 to 19.1 percent. Burlison, Van Doren, and Hackleman (*2*) reported that soybean stands declined rapidly when seed kept in ordinary storage in Illinois for 2 years or longer was used for planting. Humphries and Hurst (*3*) and Beckel and Cartter (*1*) reported on the moisture equilibrium of soybean seed at different relative humidities of the air.

The present experiment, which has been referred to briefly in connection with other work (*7, 8*), was started in 1934 to determine the effects of temperature of storage and moisture content of soybean seed on longevity. The results obtained show the hazard of attempting to keep for planting soybean seed with high seed moisture or at high temperatures. The experiment demonstrated, however, that full viability and vigor of germination of soybean seed can be maintained for at least 10 years by storing dry seed at low temperatures. This information should help farmers and seedsmen to avoid unnecessary losses of planting seed. Plant breeders, also, will be interested in the possibility of preserving valuable seed stocks for very long periods.

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MATERIALS AND METHODS

Soybean seed of the varieties Otootan and Mammoth Yellow was obtained from growers in eastern North Carolina in January 1934. This seed had been held in ordinary farm storage since harvest. Some of the seed was retained to be stored at the natural moisture content. Part of it was moisture-conditioned to a high moisture content. As a result of preliminary trials it was found that the moisture content of the seed could be raised, without apparent injury to the seed coat, by mixing with a weighed bulk of seed an equal bulk of air-dry quartz sand to which a measured amount of water had been added. It was found that the seed absorbed this water almost completely from the sand when the mixture was held in a closed container for 3 days. The moisture content of another part of the seed was reduced by spreading a layer about 2 inches deep on a concrete floor warmed by heating pipes beneath it. The seed on the floor was stirred occasionally. The temperature of the seed while drying was approximately 30° C. After about 20 hours the moisture content of the seed had been reduced approximately 5 percent and after 44 hours 8 percent. When the seed had attained approximately the desired moisture content, each lot was thoroughly mixed and sealed in pint fruit jars with glass tops and rubber sealing rings.

The expected moisture contents of the seed were 18, 13.5 (natural), 9, and 5 percent. The actual moisture contents of the seed as stored were 18.1, 13.9, 9.4, and 5.4 percent for Mammoth Yellow, and 17.9, 13.4, 8.1, and 5.2 percent for Otootan. Except for samples reserved for immediate moisture determination and germination tests, several jars of seed of each moisture content were placed immediately in chambers maintained at −10°, 2°, 10°, 20°, and 30° C.

The 30° C. storage chamber was a refrigerator box with the cooling unit removed; a long coil heater was placed around the floor of the box and controlled by a mercury thermostat and a relay. The other storage chambers were electric refrigerators; a mercury thermostat and a relay were substituted for the usual temperature control to obtain less variation. At intervals enough seed for germination tests was removed from a jar at each storage condition, and the jar was quickly resealed. In the early part of the experiment germination tests were made in paper toweling at controlled temperatures (20° for 17 hours and 30° for 7 hours each day). Later all tests were conducted in sterilized soil in a greenhouse. In the course of seed deterioration loss of life usually is not uniform for all tissues of the seed. Seeds that made some growth but produced seedlings incapable of continued development were not counted as germinated.

GERMINATION AFTER STORAGE

Before storage the germination of the seed of the Mammoth Yellow was 97 percent and that of the Otootan 93 percent. The record of subsequent germination tests of seed of 3 moisture contents is given in table 1. These germination percentages are averages of 2 tests of 100 seeds each. The results are summarized graphically in figure 1.

The seed with the highest moisture content (approximately 18 percent) lost viability extremely rapidly at the higher temperatures, but maintained good germination for 5 to 6 years at −10° C. Loss of viability was associated with growth of fungi on the seeds, even at −10°.

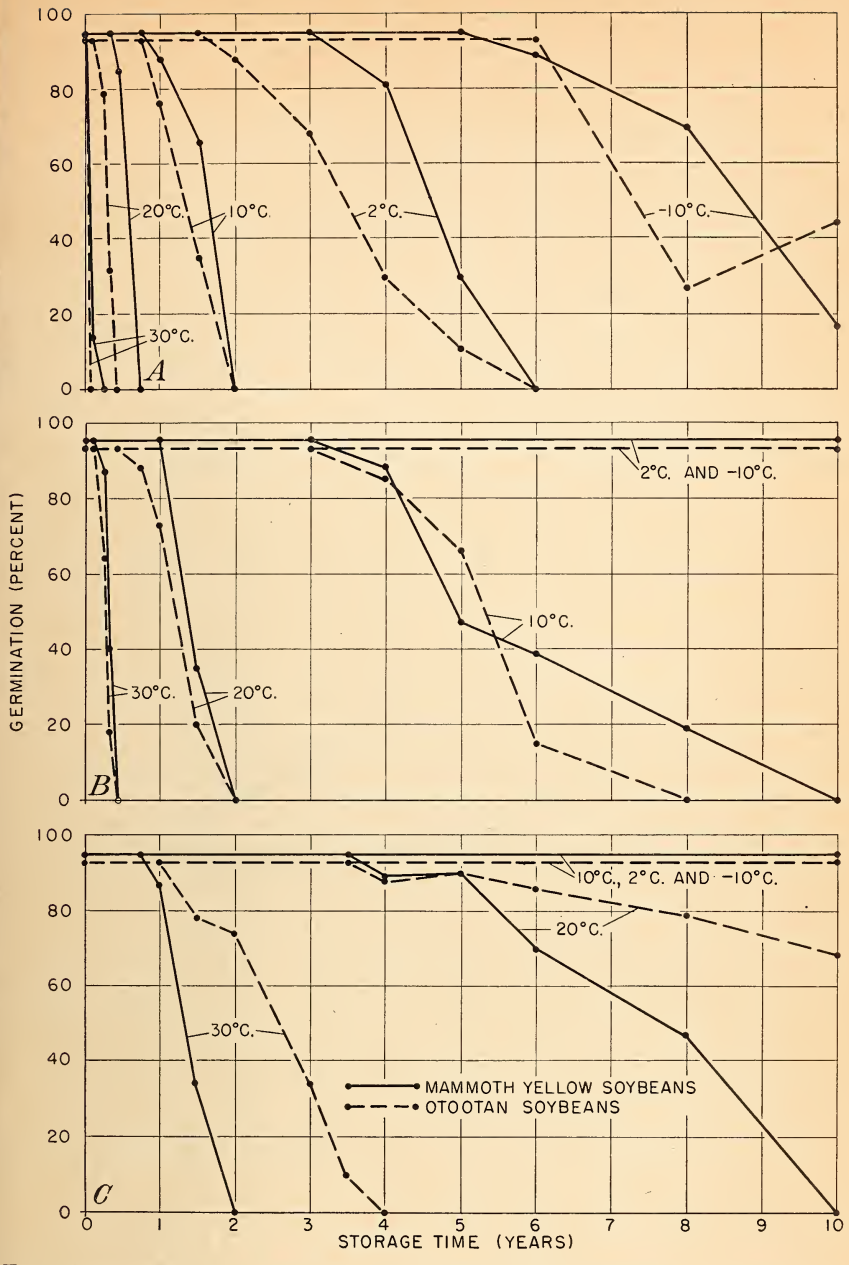

FIGURE 1.—Viability of soybean seed stored at five temperatures with three moisture contents: *A*, High moisture (18.1 percent for Mammoth Yellow; 17.9 for Otootan); *B*, natural moisture (13.9 for Mammoth Yellow; 13.4 for Otootan); *C*, reduced moisture (9.4 for Mammoth Yellow; 8.1 for Otootan). In order to avoid congestion of lines an average value is shown as a straight line until loss of viability became evident.

The seed with natural moisture (13.9 percent for Mammoth Yellow and 13.4 percent for Otootan) also fell rapidly in germination when stored at 30° and 20° C. There was no loss, however, until after 3 years at 10°. Practically full germination was held for 10 years at 2°, although the vigor of the seedlings was noticeably weakened (fig. 2, *A* and *B*); at −10° the original germination was maintained.

TABLE 1.—*Germination of seed of Mammoth Yellow and Otootan soybeans stored February 1, 1934, with different moisture contents at various temperatures*

Variety and date of test	Approximate time in storage	Seed germinating when stored under indicated conditions of moisture and temperature (°C.)														
		High moisture content [1]					Natural moisture content [2]					Reduced moisture content [3]				
		30°	20°	10°	2°	−10°	30°	20°	10°	2°	−10°	30°	20°	10°	2°	−10°
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Mammoth Yellow:	*Mo.*															
Mar. 13, 1934	1	14	93	97	----	----	98	99	97	----	----	----	----	----	----	----
May 3, 1934	3	0	96	91	94	98	87	99	96	97	96	97	96	96	98	98
June 6, 1934	4	0	94	96	94	96	40	97	91	96	93	98	95	94	98	94
July 10, 1934	5	0	85	96	98	97	0	98	95	94	96	96	97	93	94	96
Nov. 14, 1934	9	----	0	94	96	94	----	97	98	94	93	95	99	89	89	91
Feb. 7, 1935	12	----	0	88	97	96	----	93	98	95	93	87	99	95	93	93
Aug. 15, 1935	18	----	----	66	95	----	----	35	99	99	----	34	97	95	91	----
Feb. 17, 1936	24	----	----	1	97	99	----	0	96	97	96	0	96	98	94	96
Mar. 23, 1937	37	----	----	----	92	94	----	0	92	97	----	0	94	93	96	----
Aug. 10, 1937	42	----	----	----	----	94	----	----	87	98	97	----	95	96	96	93
Feb. 26, 1938	48	----	----	----	81	95	----	----	88	96	98	----	89	99	96	94
Mar. 17, 1939	61	----	----	----	30	93	----	----	47	97	97	----	90	92	97	98
Feb. 21, 1940	72	----	----	----	0	89	----	----	39	98	97	----	70	96	97	99
Feb. 24, 1942	96	----	----	----	----	70	----	----	19	95	98	----	47	93	94	95
Feb. 3, 1944	120	----	----	----	----	17	----	----	0	90	98	----	0	94	95	92
Otootan:																
Mar. 13, 1934	1	0	92	91	----	----	92	93	94	----	----	----	----	----	----	----
May 3, 1934	3	0	79	95	94	94	64	94	95	90	94	88	94	88	93	92
June 6, 1934	4	0	32	94	94	94	18	91	95	91	95	91	92	93	93	92
July 10, 1934	5	0	0	89	90	94	0	93	92	94	91	89	94	94	90	92
Nov. 14, 1934	9	----	0	89	92	94	----	88	94	91	93	92	96	90	89	93
Feb. 7, 1935	12	----	----	76	92	96	----	73	92	93	89	91	95	88	94	94
Aug. 15, 1935	18	----	----	35	88	----	----	20	94	92	----	78	92	93	94	----
Feb. 17, 1936	24	----	----	0	88	92	----	0	93	95	93	74	92	88	93	90
Mar. 23, 1937	37	----	----	0	68	93	----	0	95	96	----	34	98	93	96	----
Aug. 10, 1937	42	----	----	----	61	91	----	----	90	92	92	10	93	93	95	95
Feb. 26, 1938	48	----	----	----	30	83	----	----	85	93	90	1	88	95	95	89
Mar. 17, 1939	61	----	----	----	11	95	----	----	66	95	94	----	90	93	95	92
Feb. 21, 1940	72	----	----	----	0	93	----	----	15	92	94	----	86	93	98	91
Feb. 24, 1942	96	----	----	----	----	27	----	----	0	94	98	----	79	94	96	94
Feb. 3, 1944	120	----	----	----	----	44	----	----	----	91	98	----	68	95	93	94

[1] 18.1 percent for Mammoth Yellow and 17.9 percent for Otootan.
[2] 13.9 percent for Mammoth Yellow and 13.4 percent for Otootan
[3] 9.4 percent for Mammoth Yellow and 8.1 percent for Otootan.

The seed that had been dried for 20 hours at approximately 30° C. (9.4 percent moisture for Mammoth Yellow and 8.1 percent for Otootan) showed only slight loss of viability after storage for a year at 30°, but it deteriorated rapidly thereafter. At 20° no loss of germination was evident for 3½ years and no serious loss until after 5 years. The original viability was maintained for the full 10 years at 10°, 2°, and −10° (fig. 2, *C* and *D*).

When the moisture contents of the two varieties were approximately the same, the seed of Mammoth Yellow had a tendency to remain viable longer than that of Otootan. It is not clear whether this is a varietal difference or is associated with the higher original viability of the seed of Mammoth Yellow. With the dried seed the difference in moisture content of 1.3 percent resulted in noticeably longer life for the drier seed (Otootan).

It seemed desirable to determine the field behavior of the 10-year-

old seed that had shown no loss in germination. Small field plantings were therefore made [1] in comparison with those of seed grown the previous year. There was no apparent difference in vigor of growth

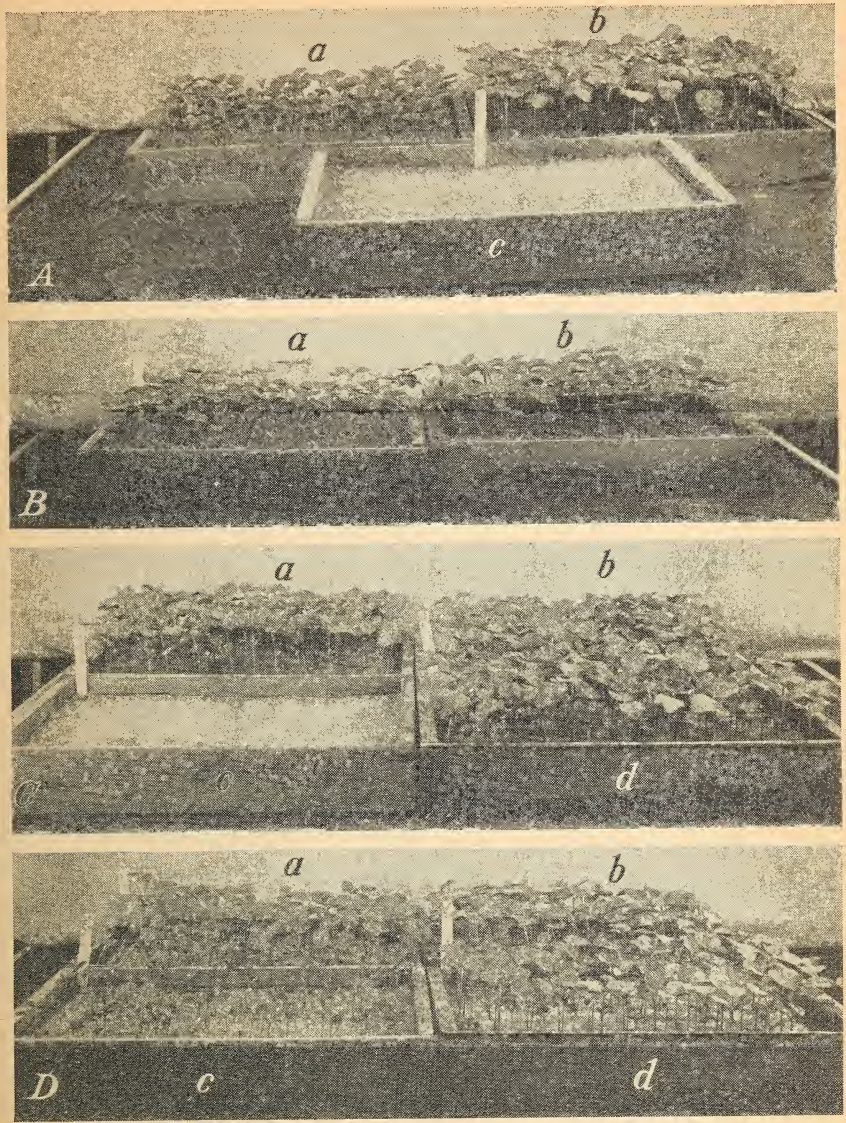

FIGURE 2.—Greenhouse germination of soybean seed stored under controlled conditions for 10 years and photographed 3 weeks after planting. *A*, Mammoth Yellow stored with 13.9 percent moisture: *a*, At 2° C.; *b*, at −10°; *c*, at 10°. *B*, Otootan stored with 13.4 percent moisture: *a*, At 2°; *b*, at −10°. *C*, Mammoth Yellow stored with 9.4 percent moisture: *a*, At 2°; *b*, at −10°; *c*, at 20°; *d*, at 10°. *D*, Otootan stored with 8.1 percent moisture: *a*, At 2°; *b*, at −10°; *c*, at 20°; *d*, at 10°.

[1] The field plantings were made by Mr. William M. Stuart, Jr., of the Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering.

of either variety or in plant development except that the new seed of Mammoth Yellow was from a more upright growing strain than the stored seed.

As mentioned under "Materials and Methods," part of the seed of each variety was dried for 44 hours; that of Mammoth Yellow had a moisture content of 5.4 percent when stored and that of Otootan 5.2 percent. When this seed was first tested for germination, after storage for 3 months, many abnormalities were noticed in the seedlings, especially in those from seed held at the lower temperatures. Few abnormal seedlings were produced from the seed stored at 30° C., but they were increasingly numerous at successively lower storage temperatures. The abnormalities of Mammoth Yellow were much more frequent and more pronounced than those of Otootan. Subsequent tests showed approximately the same proportion of abnormalities.

Many of the seedlings from this low-moisture seed, especially those of Mammoth Yellow, had deep cracks across the cotyledons. This injury by itself did not seem to prevent normal development. In other seedlings there seemed to be a more or less complete severance of the vascular connection of some cotyledons; this interfered with the utilization of stored food and caused various types of abnormal seedlings. Figure 3 shows some of the abnormal seedlings of Mammoth Yellow planted in soil in a humid germination chamber. In addition, in a fairly uniform proportion of seeds the plumule was severed completely. In contrast to most baldheads encountered in commercial seed, the seedlings produced showed no injury to the axillary buds, which developed rapidly. The seedlings soon equalled in height and vigor those not showing this injury.

Because of the abnormal behavior of this seed with the lowest

TABLE 2.—*Germination of seed of Mammoth Yellow and Otootan soybeans stored February 1, 1934, with low moisture* [1] *contents at various temperatures*

Variety and date of test	Seed germinating when stored at (°C.)—				
	30°	20°	10°	2°	−10°
Mammoth Yellow:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
May 3, 1934	95	79	65	57	48
June 6, 1934	95	75	61	56	50
July 10, 1934	94	74	60	65	45
Nov. 14, 1934	96	72	64	54	52
Feb. 7, 1935	94	70	61	54	43
Aug. 15, 1935	91	74	58	59	----
Feb. 17, 1936	88	72	66	58	44
Mar. 23, 1937	84	77	57	63	----
Feb. 26, 1938	64	72	68	58	59
Mar. 17, 1939	37	70	60	62	62
Feb. 21, 1940	1	56	50	54	56
Feb. 24, 1942	1	70	64	66	----
Feb. 3, 1944	0	60	59	55	----
Otootan:					
May 3, 1934	92	91	83	84	83
June 6, 1934	92	89	92	90	86
July 10, 1934	94	90	90	89	84
Nov. 14, 1934	92	92	90	84	91
Feb. 7, 1935	86	90	87	88	79
Aug. 15, 1935	87	89	92	91	----
Feb. 17, 1936	80	88	92	90	81
Mar. 23, 1937	67	86	88	90	----
Feb. 26, 1938	34	80	88	88	82
Mar. 17, 1939	39	87	91	86	91
Feb. 21, 1940	40	81	73	91	89
Feb. 24, 1942	8	79	88	87	91
Feb. 3, 1944	4	55	66	92	82

[1] 5.4 percent moisture for Mammoth Yellow; 5.2 percent moisture for Otootan.

moisture content, the germination results are given separately in table 2. The percentages include seedlings that were normal except for cracks in the cotyledons and those with no central stem but with vigorous axillary shoots. At 30° C. injury was so slight that the germination results probably represent the normal storage behavior of seed with this moisture content. At the lower temperatures germination was progressively lower as the temperature of storage was

FIGURE 3.—Abnormal seedlings of Mammoth Yellow soybeans from seed dried to 5.4 percent moisture and placed immediately in storage at −10° C. for 6 months and grown in soil in a humid germination chamber: *A*, With plumule destroyed and also injured at attachment of cotyledon; *B* and *C*, injured at attachment of cotyledon; *D*, without serious injury except cracking of cotyledon; *E*, normal except for slight injury at base of one cotyledon.

lowered, but there was no consistent change during the course of the experiment.

Since more injury occurred at the lower temperatures and little or no injury with storage at 30° C. (the approximate temperature of drying), it was believed that the sudden change of temperature of the seed accounted for the injury. After 5½ months of storage a jar of seed of each variety was moved from 30° to −10°. Tests conducted during the next several months gave no indication of injury to germination as a result of this sudden change of temperature of the seed. The following explanation of the original injury of the low-moisture seed is suggested. With the comparatively rapid drying when the seed moisture content was adjusted, it is probable that the outer part of the seed was much drier than the interior. This difference was undoubtedly greater with the larger, nearly spherical seeds of Mammoth Yellow than with the smaller, flattened ones of Otootan. Suddenly changing the temperature of this seed when it was first placed at the different storage temperatures might easily increase the internal stresses and account for the injuries encountered. The seed stored at 30° would be expected to reach uniform moisture without undue changes in the tissues. This partial failure of this experiment is described in detail, since it illustrates a possible hazard in drying large seeds, both in experimental work and in commercial practice.

SUMMARY

Seed of Mammoth Yellow and Otootan soybeans grown in North Carolina in 1933 was adjusted to four different moisture contents and stored at five controlled temperatures. The moisture content was maintained by sealing the seed in glass fruit jars with rubber seals. The seed was stored in February 1934 and tested at intervals until February 1944.

The two varieties gave essentially the same results.

Seed with approximately 18 percent moisture was dead in 1 to 3 months at 30° C., in 5 to 9 months at 20°, and in 2 years at 10°. At 2° this seed maintained nearly full viability for 2 to 3 years, but it was dead in 6 years. Nearly full germination was obtained after 6 years at −10°, but the seed was worthless for planting after 10 years.

With the natural moisture of approximately 13.5 percent the seed was dead after 5 months' storage at 30° C. and after 2 years at 20°. Full viability was kept for 3 years at 10°, but germination fell rapidly after that. Practically full germination was maintained for 10 years at 2° and full germination at −10°.

Seed dried to 8 to 9 percent moisture showed little or no loss of germination when stored at 30° C. for 1 year, but the fall in germination was very rapid after 1 year. Seed stored at 20° germinated 90 percent after 5 years and lost viability gradually in subsequent years. This seed stored at 10°, 2°, and −10° did not change in germination in 10 years.

Seed dried from approximately 13.5 to approximately 5 percent in 44 hours showed severe injury to germination when stored at low temperatures.

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